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Escapement Goal Review for Copper River, Bering River, and Prince William Sound Salmon Stocks

by

Matthew J. Evenson,

James J. Hasbrouck,

Steven D. Moffitt, and

Lowell Fair

October 2008

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tailfork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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Matthew J. Evenson
James J. Hasbrouck
Steven D. Moffitt
and
Lowell Fair

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Matthew J. Evenson
Alaska Department of Fish and Game, Division of Sport Fish,
1300 College Road, Fairbanks AK, 99701, USA

James J. Hasbrouck,
Alaska Department of Fish and Game, Division of Sport Fish
333 Raspberry Road, Anchorage, AK 99518, USA

Steven D. Moffitt
Alaska Department of Fish and Game, Commercial Fisheries
401 Railroad Avenue, Cordova, AK 99574, USA

and

Lowell Fair
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, AK 99518, USA

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This report is a summary of reviews and recommendations for escapement goals for the major salmon stocks of the Copper River, Bering River, and Prince William Sound areas. An interdivisional team including staff from Commercial Fisheries and Sport Fish Divisions held three formal meetings to discuss and develop recommendations. Escapement goals were reviewed based on the Policy for the Management of Sustainable Salmon Fisheries (SSFP; 5 AAC 39.222) and the Policy for Statewide Salmon Escapement Goals (EGP; 5 AAC 39.223) adopted by The Board of Fisheries into regulation in 2001. The team reviewed 17 existing escapement goals for: one Chinook salmon stock, seven chum salmon stocks, two coho salmon stocks, one pink salmon stock (one goal for each even and odd year broodline), and five sockeye salmon stocks. All but two of these goals were adopted in 2002, while the two coho salmon goals were adopted in 1991. The team recommends that all goals for Chinook, coho, and pink salmon remain the same. For Coghill Lake sockeye salmon, the team recommends that the goal be changed from a BEG to an SEG, but that the range remain the same. This recommendation was made because the goal is based primarily on limnology data and not from a spawner-recruit relationship that defines the escapement that produces maximum sustained yield. The remaining four sockeye salmon goals were unchanged. For Prince William Sound chum salmon stocks, the team recommends that seven goals be changed from SEG ranges to SEG thresholds because they are a non targeted species and are not actively managed for escapements to fall within the existing range.

Key words: Copper River, Bering River, Prince William Sound, escapement goal, biological escapement goal, sustainable escapement goal, Chinook salmon, chum salmon, sockeye salmon, coho salmon, pink salmon

INTRODUCTION

This report is a summary of reviews and recommendations for escapement goals for the major salmon stocks of the Copper River, Bering River and Prince William Sound areas. An interdivisional team including staff from Commercial Fisheries and Sport Fish Divisions held formal meetings to discuss and develop recommendations on February 7, May 6 and October 21, 2005. Escapement goals were reviewed based on the Policy for the Management of Sustainable Salmon Fisheries (SSFP; 5 AAC 39.222) and the Policy for Statewide Salmon Escapement Goals (EGP; 5 AAC 39.223) adopted by The Alaska Board of Fisheries (BOF) into regulation in 2001 to ensure that the state's salmon stocks are conserved, managed, and developed using the sustained yield principle. The EGP states that it is the Department's responsibility to document existing salmon escapement goals for all salmon stocks that are currently managed for an escapement goal and to review existing, or propose new escapement goals on a schedule that conforms to the BOF's regular cycle of consideration of area regulatory proposals.

This was the fourth time an interdivisional team has reviewed escapement goals for stocks in this area. In 1994 and 1999, teams reviewed and recommended goals with guidance from the Department's Salmon Escapement Goal Policy adopted in 1992 (Fried 1994). The most recent escapement goal review was conducted in 2002 (Bue et al. 2002). During that review, most of the escapement goals were revised to be compliant with the SSFP and EGP. Following extensive reviews and analysis in 2002, 15 escapement goals were adopted for 1 Chinook salmon *Oncorhynchus tshawytscha* stock, 5 chum salmon *O. keta* stocks, 2 coho salmon *O. kisutch* stocks, 1 pink salmon *O. gorbuscha* stock (same goals for even and odd-year broodlines), and 5 sockeye salmon *O. nerka* stocks. Twelve of the goals were sustainable escapement goals (SEG), and two were biological escapement goals (BEG). The SSFP defines biological and sustainable escapement goals as:

> "*Biological Escapement Goal*: means the escapement that provides the greatest potential for maximum sustained yield; BEG will be the primary management objective for the escapement unless an optimal escapement or inriver run goal has been adopted; BEG will be

developed from the best available biological information, and should be scientifically defensible on the basis of available biological information; BEG will be determined by the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements within the bounds of a BEG."

and

"*Sustainable Escapement Goal*: means a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situations where a BEG cannot be estimated due to the absence of a stock specific catch estimate; the SEG is the primary management objective for the escapement, unless an optimal escapement or inriver run goal has been adopted by the board, and will be developed from the best available biological information; the SEG will be determined by the department and will be stated as a range that takes into account data uncertainty; the department will seek to maintain escapements within the bounds of the SEG."

OBJECTIVES

Objectives of the 2005 review were to:

1) review all existing goals to determine whether they are still appropriate given: new data collected since the last review, current assessment techniques, and current management practices;
2) review the methods used to establish the existing goals and determine whether alternative methods should be investigated;
3) consider new stocks for which there may be sufficient data to develop a goal; and,
4) Recommend new goals if appropriate.

METHODS AND RECOMMENDATIONS

The team reviewed each of the existing escapement goals in light of new escapement and harvest data collected since the last review in 2002. Most of the existing escapement goals are SEGs developed with the algorithm used to estimate sustainable escapement goals of Upper Cook Inlet salmon stocks (Bue and Hasbrouck 2001; Table 1). There is still considerable debate within the Department as to methodologies for setting SEGs. The team agreed that the Bue and Hasbrouck method has a high probability of replicating the returns historically observed for a stock and that it is a descriptive method not based on a determination of the relationship between spawners and recruitment. However, for most of the salmon stocks in the area, these relationships cannot be examined due to lack of stock-specific estimates of harvest and/or total estimates of escapement.

Table 1.–Algorithm used to estimate sustainable escapement goals (SEGs) of Upper Cook Inlet salmon stocks (Bue and Hasbrouck 2001).

Contrast of Observed Escapements [a]	Range of SEG
Low (<4)	15th percentile - Maximum
Medium (4-8)	15th and 85th percentile
High (>8) and at most low exploitation	15th and 75th percentile
High (>8) and at least moderate exploitation	25th and 75th percentile

[a] Relative range of the entire series of escapement data calculated by dividing the maximum observed escapement by the minimum observed escapement.

Two of the existing goals are BEGs (Eshamy Lake and Coghill Lake sockeye salmon). These stocks had data exhibiting a wide range of escapements, harvest across this range of escapements, and age composition on the commercial harvest and escapement of the returns. Methods described in Hilborn and Walters (1992), Chinook Technical Committee (1999), and Quinn and Deriso (1999) were followed in estimating BEGs.

Of the 15 current escapement goals, the team recommends that the one Chinook, two coho, two pink, and four of the five sockeye goals remain unchanged. For Coghill Lake sockeye salmon, the team recommend that the goal be changed from a BEG to an SEG, but that the range remain unchanged. This recommendation was made because the goal is based primarily on limnology data and not a spawner-recruit relationship that specifically estimates the number of spawners at MSY. For chum salmon, the team recommends that the five goals be changed from SEG ranges to SEG thresholds because they are harvested incidentally in the directed pink salmon fishery and their escapements cannot be effectively managed to fall within a range (Table 2). A stock-by-stock summary of each recommendation follows along with a detailed description of the methods used to develop the SEG thresholds for chum salmon.

COPPER RIVER CHINOOK SALMON

We recommend the SEG of 24,000 or more spawners established in 2002 (Bue et al. 2002) remain unchanged. As in 2002, the review team recommends the fishery be managed for escapements that, on average, match the historical average escapement of 26,000 as determined from model estimates using catch-age analysis. A draft review of this analysis (Savereide *In prep*) has been provided to the Board of Fisheries. Since 1999, mark-recapture techniques along with estimates of inriver harvest have been used to estimate total drainage escapement to evaluate whether the escapement goal has been reached and to validate and refine model estimates of escapement. Escapement estimates have had low contrast (covered a narrow range), indicating past escapements were within a range too narrow to provide information sufficient for estimating a stock-recruit relationship. However, the average escapement since 1980 (~26,000 salmon) has produced an average annual harvest near 48,000 salmon. No new information on production by this stock will be forthcoming until escapements occur that are higher than those observed in the recent past. Most estimates of escapement since 1980 have been less than 40,000 Chinook salmon. The largest estimated escapement was ~50,000 Chinook salmon. Recent (measured) estimates have ranged from 16,000-35,000 Chinook salmon (Appendix A1). Because actively managing for higher escapements would be disruptive to the commercial, subsistence, personal use, and sport fisheries, the team recommends at least 24,000 Chinook salmon be allowed to spawn annually. This threshold was chosen to keep future escapements near the historical average without precluding the possibility that exceptionally large returns will provide new information with higher escapements.

COPPER RIVER DELTA AND BERING RIVER COHO SALMON

We recommend the SEG of 13,000–33,000 spawners for Bering River and the SEG of 32,000-67,000 spawners for Copper River delta established in 2002 (Bue et al. 2002) remain unchanged. We examined an alternative approach to setting the coho salmon escapement goals using a lagged harvest versus escapement relationship (pseudo brood table) and explored the option of establishing a threshold SEG (based on a historical average escapement index or current SEG lower bound); however, these approaches did not appear to provide any benefit over the existing SEG ranges. Lack of stock-specific harvest information and index measurements of escapement (peak aerial survey counts) preclude development of a spawner-recruit relationship (Appendices A2-A3).

ESHAMY LAKE SOCKEYE SALMON

We recommend the BEG of 20,000–40,000 spawners established in 2002 (Bue et al. 2002) remain unchanged. Escapement into Eshamy Lake has been visually counted through a weir since 1931 (Pirtle 1978), but reliable age composition data were not available until 1970. Therefore, the spawner-recruit analysis used only complete brood years beginning with 1970 (Bue et al. 2002).

For this review we updated the Markov yield table, the Ricker model, and examined models to estimate escapements for times when a weir was not in place. Since the 2002 review, the three additional years (1996–1998 brood years) produced little change in the estimate of spawners most likely to produce maximum sustained yield (S_{MSY}; ~22,000 versus ~21,000 spawners; Appendix A4). Eshamy Lake sockeye salmon have protracted and highly variable escapement timing (late June through late September). Currently, ADF&G has the ability to maintain a weir enumeration camp for approximately 2 months. Therefore, an attempt was made to model escapements not enumerated during weir operations (approximately July and August). Daily rainfall data collected at the Main Bay Hatchery was correlated with daily sockeye salmon passage at the Eshamy Lake weir to model escapements outside of the current weir project timing. The models fit very poorly (r^2 = from 0.01 to 0.34) for daily rainfall versus daily weir passage with no lag or lagged by one, two, or three days. Additional models with restricted data sets (daily rainfall > 1.0 inch) also produced poor model fits. There was also little change in the Markov yield tables (complete brood years 1974–1998; Appendix A4) since the 2002 escapement goal review (Bue et al. 2002).

The escapement goal range was set in 2002 by examination of both the Ricker model and the Markov yield table. Although the Ricker model would suggest a lower range, the Markov yield table showed higher yields with escapements up to 40 to 50 thousand. A range 20-40 thousand would include all escapement bins producing yields >50,000 and include the Ricker model estimate of S_{MSY} (Appendix A4).

Table 2.–Summary of escapement goals for Copper and Bering rivers and Prince William Sound salmon stocks, 2005.

	Current Goal		Recommended Goal				
System	Goal	Year Adopted	Type	Range	No. Years	Escapement Data	Action
Chinook Salmon							
Copper River	>24,000	2002	SEG	>24,000	6	Mark Recapture	No Change
Coho Salmon							
Bering River	13,000 - 33,000	1991	SEG	13,000 – 33,000	21	Aerial Survey	No Change
Copper River delta	32,000 - 67,000	1991	SEG	32,000 – 67,000	24	Aerial Survey	No Change
Sockeye Salmon							
Eshamy Lake	20,000 - 40,000	2002	BEG	20,000 - 40,000	27	Weir	No Change
Coghill Lake	20,000 - 40,000	2002	SEG	20,000 - 40,000	20	Weir	Change to SEG
Bering River	20,000 - 35,000	2002	SEG	20,000 - 35,000	16	Aerial Survey	No Change
Copper River delta	55,000 – 130,000	2002	SEG	55,000 – 130,000	34	Aerial Survey	No Change
Upper Copper River	300,000 – 500,000	2002	SEG	300,000 – 500,000	27	Sonar	No Change
Pink Salmon							
Even-Year Broodline (All Districts Combined)							
	1,250,000 - 2,750,000	2002	SEG	1,250,000 - 2,750,000	24	Aerial Survey	No Change
Odd-Year Broodline (All Districts Conbined)							
	1,250,000 - 2,750,000	2002	SEG	1,250,000 - 2,750,000	24	Aerial Survey	No Change
Chum Salmon (by District)							
Coghill	8,000 - 25,000	2002	SEG	8,000 and up	40	Aerial Survey	Change
Eastern	50,000 - 130,000	2002	SEG	50,000 and up	40	Aerial Survey	Change
Northern/Unakwik	20,000 – 60,000	2002	SEG	20,000 and up	40	Aerial Survey	Change
Northwestern	5,000 - 19,000	2002	SEG	5,000 and up	40	Aerial Survey	Change
Southeastern	15,000 - 20,000	2002	SEG	8,000 and up	40	Aerial Survey	Change

COGHILL LAKE SOCKEYE SALMON

We recommend the BEG of 20,000–40,000 spawners established in 2002 (Bue et al. 2002) be changed to an SEG; however, we suggest the range remain unchanged. Escapement into Coghill Lake has been visually counted since 1960. From 1960–1973 escapements were counted using a partial weir and tower with a full river weir coming into use in 1974. Age compositions from the commercial harvests and escapements have been collected since 1962. A series of large escapements (greater than 100,000 spawners from 1980–1982) produced more than 3.0 returns per spawner. However, escapements from brood years 1985–1989, including some additional escapements >100,000 spawners, did not replace themselves (less than 1.0 return per spawner). The former ADF&G limnology lab suggested poor production from the 1985–1989 brood years was due to grazing pressure of high densities of sockeye salmon fry resulting in low densities of cyclopoid copepods (Edmundson et al. 1992). Because of the apparent reduced productivity, the lake was fertilized (1993-1996) to increase the zooplankton abundance. Additionally, the outmigrating smolt abundance was estimated in 1989-1991 and 1993-1997. Although the mean number of smolt increased significantly after fertilization (from ~263,000 before fertilization to ~940,000 after fertilization), the mean size of the outmigrating smolt remained < 1.5 g (Edmundson et. al. 1997).

For this review we updated the Markov yield table, examined the relationship between spawners and estimates of resulting smolt production, examined a Ricker-type model using only complete brood years with escapements estimated from a full weir (1974–1998), and examined zooplankton data collected from 2002 through 2004. The three years of additional yield data did not appreciably change average yield values from the Markov yield table (Appendix A5). Complete smolt production estimates were only available for 5 brood years and the fit of the data was poor ($r^2 = 0.074$). The Ricker model suggested ~54,000 spawners are most likely to produce maximum sustained yield (Appendix A5). However, zooplankton data collected between 1985 and 1998 suggests the system productivity has not remained stable (Appendix A5). From 2002 to 2004, zooplankton abundance has remained fairly stable; however associated escapements were reasonably low (28,000–75,000 spawners). The Ricker model estimate of spawners required for maximum sustained yield may be too high for the forage base (Edmundson et al. 1995; Koenings and Kyle 1997). A plot of the Ricker model residuals by year shows a run of six years of negative residuals indicating nonstationarity. We recommend the current goal range of 20,000-40,000 spawners remain unchanged. However, because the goal is based primarily on zooplankton data and not a spawner-recruit relationship that specifically estimates the number of spawners at MSY, we recommend the goal type be changed from a BEG to an SEG.

BERING RIVER DISTRICT SOCKEYE SALMON

No change in the Bering River sockeye salmon SEG is recommended for 2005. The SEG of 20,000–35,000 aerial index points was established in 2002 using the method of Bue and Hasbrouck (2001). Because there were only 3 years of additional data without an increase in contrast of escapements, no new suggested analysis methods, and an extensive review in 2002 (Bue et al. 2002), no further review was performed for this stock (Appendix A6).

COPPER RIVER DELTA SOCKEYE SALMON

No change in the Copper River delta sockeye salmon SEG is recommended for 2005. The current SEG of 55,000–130,000 aerial index points was established in 2002 (Bue et al. 2002) using the method of Bue and Hasbrouck (2001). In 2002, the review team recommended that the fishery be managed for escapements that, on average, match the historical average escapement of 84,500. Because there were only 3 years of additional data without an increase in contrast of escapements, no new suggested analysis methods, and an extensive review in 2002 (Bue et al. 2002), no further review was performed for this stock (Appendix A7).

UPPER COPPER RIVER SOCKEYE SALMON

No change in the Upper Copper River sockeye salmon SEG is recommended for 2005. The SEG of 300,000–500,000 spawners was established in 2002 using the method of Bue and Hasbrouck (2001). In 2002, the review team recommended that the fishery be managed for escapements that, on average, match the historical average escapement of 361,000. Because there were only 3 years of additional data without an increase in contrast of escapements, no new suggested analysis methods, and an extensive review in 2002 (Bue et al. 2002), no further review was performed for this stock (Appendix A8).

PRINCE WILLIAM SOUND PINK SALMON

No changes in the Prince William Sound pink salmon SEGs are recommended for 2005. In 2002, escapement goals for Prince William Sound pink salmon were changed from BEGs to SEGs, and a Sound-wide goal of 1,250,000-2,750,000 for both the even and odd-year brood lines was established (Bue et al. 2002). Although a Sound-wide goal was established, the fishery should be managed to distribute the goal to the fishing districts similar to the historical escapement distribution. An extensive review of data and analysis methods was conducted in 2002, and the goals established were based on examination of Markov yield tables for each brood line (Bue et al. 2002). In 2005, no new analytical methods were suggested and only one year of additional data were available for each brood line (Appendices A9–A10). Therefore, the team did not conduct any additional review of the PWS pink salmon escapement goals.

PRINCE WILLIAM SOUND CHUM SALMON

In 2002, all escapement goals for Prince William Sound chum salmon were changed from BEGs to SEGs (Bue et al. 2002), and two goals, Montague and Southwestern District chum salmon, were removed from the list of existing goals. The Unakwik District (part of the Northern District until 1989) does not contain any chum salmon index streams and no goal was created.

Escapement goals for chum salmon are based on expanded counts from aerial surveys dating back to 1965. Streams are flown multiple times each year with escapement estimated using area-under-the-curve calculations adjusted for estimates of stream life (Bue et al. 1998). Harvest of most chum salmon has been incidental to the harvest of pink salmon throughout Prince William Sound except in terminal hatchery harvest areas. Reliable estimates of hatchery contributions to commercial harvests of chum salmon are unavailable before 2003. Likewise, there are no reliable estimates of district of origin for wild stock chum salmon with the possible exception of the Eastern and Southeastern Districts. Because of this inability to determine district of origin for wild-stock harvests, the lack of hatchery contribution estimates before 2003, and because most fisheries do not target and are not managed for chum salmon, precautionary reference points, or SEG thresholds, were estimated for the Coghill, Eastern, Northern, Northwestern, and Southeastern Districts using historical aerial indices of escapement and analyses described in Bernard et al. (*In prep*).

Methods

Escapement time series were first log-transformed and tested for normality using a one-sample Kolmogorov-Smirov test (Table 3). The time series of the total stock aggregate followed a log-normal distribution ($P > 0.15$). The log-transformed escapement time series were then tested for serial correlation using diagnostics in Abraham and Ledolter (1983). There was a significant (α=0.05) lag-1 serial correlation in escapements of chum salmon in the Eastern, Northern, Northwestern, and Southeastern districts; only escapements in the Coghill District showed no significant lag-1 correlation (Figures 1-5). Escapements of Coghill District chum salmon were modeled as log-normally distributed variables; escapements of chum salmon in the other four districts were modeled with a lag-1 autoregressive term (Table 4). Residuals of the autoregressive models had no significant serial correlation, so no further modeling was necessary. The number of consecutive years that would cause a concern was set at three, the number of years between each regularly scheduled Board of Fisheries meeting.

For Coghill District chum salmon, risk of an unwarranted restriction due to a management concern (π_k) was estimated directly from the log transformed mean (μ), standard deviation (σ), and number of consecutive years to warrant a concern (k = 3) for various values of an escapement threshold (X) as per Bernard et al. (*In prep*):

$$\hat{\pi}_k = \left\{pr\left[(N : \hat{\mu}, \hat{\sigma}^2) \leq \ln X\right]\right\}^k$$

For the remaining chum salmon stocks, direct calculation of risk of an unwarranted restriction was not possible due to the lag-1 serial correlation so simulation was required. A long escapement time series was simulated using the original escapements and the appropriate autoregressive model (Table 4). Simulated escapements were appended onto the original escapement time series to generate a total of 1,000 possible sets of three consecutive years for tabulation of estimated risk. Risk was then estimated by summing the number of times three consecutive years of escapements were below various escapement thresholds and dividing by 1,000.

Risk of detecting a drop in mean escapement was calculated in the same way as risk of an unwarranted restriction, except that the risk of not detecting ($1-\hat{\pi}_k$) was estimated and the mean escapement ($\hat{\mu}$) was changed by the desired percentage drop in mean to be detected with the threshold. Risk was estimated for drops in mean escapement of 85% to 95% depending on the stock. The maximum percentage drop in mean escapement was based on the observed percent difference between the mean escapement and the minimum escapement for each stock (89% for Coghill, 85% for Eastern, 90% for Northern, 97% for Northwestern, and 97% for Southeastern chum salmon). Recommended escapement thresholds were chosen based on minimizing risk for triggering an unwarranted concern and an approximately equal risk of failing to detect the maximum percentage drop in mean escapement as noted above.

Table 3.–Escapements (Esc) and natural log of escapements [ln(Esc)] of chum salmon stocks assessed in five fishing districts of Prince William Sound, Alaska.

	Coghill		Eastern		Northern		Northwestern		Southeastern	
Year	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)	Esc	ln(Esc)
1965	20,768	9.94	69,180	11.14	20,980	9.95	18,907	9.85	46,480	10.75
1966	10,540	9.26	75,690	11.23	24,870	10.12	5,770	8.66	9,410	9.15
1967	7,450	8.92	74,570	11.22	23,270	10.05	1,670	7.42	9,070	9.11
1968	8,780	9.08	48,960	10.80	10,620	9.27	800	6.68	4,610	8.44
1969	8,410	9.04	58,690	10.98	17,340	9.76	780	6.66	6,320	8.75
1970	11,880	9.38	34,430	10.45	4,020	8.30	2,720	7.91	7,950	8.98
1971	6,600	8.79	49,730	10.81	11,870	9.38	5,600	8.63	6,450	8.77
1972	28,160	10.25	112,950	11.63	70,760	11.17	22,980	10.04	26,990	10.20
1973	72,610	11.19	213,170	12.27	140,030	11.85	13,250	9.49	48,080	10.78
1974	29,280	10.28	72,010	11.18	55,510	10.92	6,580	8.79	3,200	8.07
1975	3,640	8.20	30,040	10.31	8,910	9.09	430	6.06	2,850	7.96
1976	25,670	10.15	16,260	9.70	29,430	10.29	8,300	9.02	770	6.65
1977	43,940	10.69	47,880	10.78	48,600	10.79	10,090	9.22	8,280	9.02
1978	18,160	9.81	90,250	11.41	27,480	10.22	12,940	9.47	6,550	8.79
1979	6,330	8.75	42,630	10.66	17,320	9.76	8,770	9.08	5,140	8.54
1980	23,340	10.06	26,720	10.19	27,880	10.24	3,060	8.03	6,710	8.81
1981	2,050	7.63	71,560	11.18	28,670	10.26	15,130	9.62	16,010	9.68
1982	22,130	10.00	146,120	11.89	68,580	11.14	21,880	9.99	25,260	10.14
1983	61,410	11.03	143,800	11.88	85,720	11.36	31,660	10.36	21,410	9.97
1984	19,690	9.89	129,190	11.77	59,080	10.99	7,920	8.98	8,650	9.07
1985	22,140	10.01	111,310	11.62	33,410	10.42	13,290	9.49	4,470	8.41
1986	13,140	9.48	126,690	11.75	50,740	10.83	17,420	9.77	8,830	9.09
1987	24,510	10.11	183,620	12.12	38,700	10.56	26,460	10.18	44,020	10.69
1988	39,240	10.58	258,560	12.46	75,420	11.23	40,780	10.62	66,930	11.11
1989	22,680	10.03	112,080	11.63	46,470	10.75	27,430	10.22	22,640	10.03
1990	26,020	10.17	115,100	11.65	112,480	11.63	37,020	10.52	7,275	8.89
1991	6,070	8.71	86,360	11.37	19,080	9.86	8,960	9.10	9,203	9.13
1992	10,003	9.21	48,804	10.80	12,903	9.47	11,072	9.31	3,881	8.26
1993	8,430	9.04	54,102	10.90	24,975	10.13	18,966	9.85	19,172	9.86
1994	14,176	9.56	40,476	10.61	23,942	10.08	12,992	9.47	4,057	8.31
1995	11,596	9.36	75,655	11.23	28,899	10.27	4,883	8.49	23,200	10.05
1996	19,669	9.89	137,908	11.83	55,568	10.93	24,405	10.10	47,334	10.76
1997	3,101	8.04	93,146	11.44	19,429	9.87	8,387	9.03	43,274	10.68
1998	22,764	10.03	86,227	11.36	28,867	10.27	7,553	8.93	52,103	10.86
1999	5,057	8.53	242,713	12.40	36,691	10.51	4,544	8.42	36,181	10.50
2000	20,488	9.93	196,253	12.19	23,655	10.07	10,150	9.23	34,969	10.46
2001	13,388	9.50	198,683	12.20	75,473	11.23	6,373	8.76	37,526	10.53
2002	7,430	8.91	94,046	11.45	30,531	10.33	16,194	9.69	104,906	11.56
2003	19,729	9.89	198,921	12.20	44,272	10.70	12,736	9.45	116,131	11.66
2004	9,685	9.18	108,833	11.60	42,456	10.66	10,371	9.25	42,344	10.65

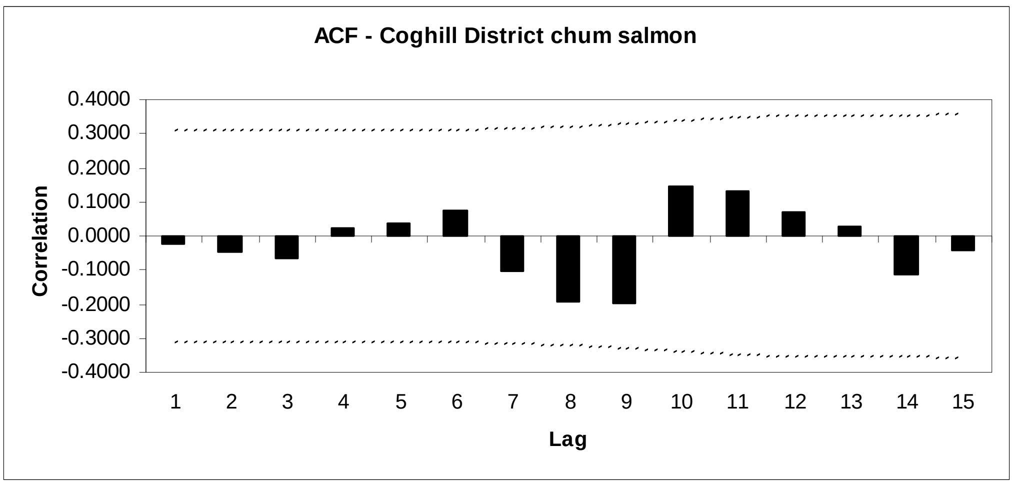
-continued-

Table 3.–Page 2 of 2.

Year	Coghill Esc	Coghill ln(Esc)	Eastern Esc	Eastern ln(Esc)	Northern Esc	Northern ln(Esc)	Northwestern Esc	Northwestern ln(Esc)	Southeastern Esc	Southeastern ln(Esc)
t[a]	40		40		40		40		40	
Mean	18,754	9.56	103,083	11.36	40,123	10.37	12,981	9.10	24,966	9.58
Min	2,050	7.63	16,260	9.70	4,020	8.30	430	6.06	770	6.65
Max	72,610	11.19	258,560	12.46	140,030	11.85	40,780	10.62	116,131	11.66
SD	14,824	0.78	61,837	0.64	28,566	0.72	9,843	1.04	26,501	1.13
CV	79.0%	8.2%	60.0%	5.7%	71.2%	6.9%	75.8%	11.4%	106.2%	11.7%
Median	16,168	9.68	88,305	11.39	29,165	10.28	10,261	9.24	12,710	9.42
Q25[b]	8,425	9.04	53,009	10.88	22,698	10.03	6,222	8.73	6,525	8.78
Q75[b]	22,908	10.04	131,370	11.79	51,933	10.86	17,792	9.79	38,731	10.56

[a] Refers to length of time series.

[b] Refers to 25th and 75th quartiles.



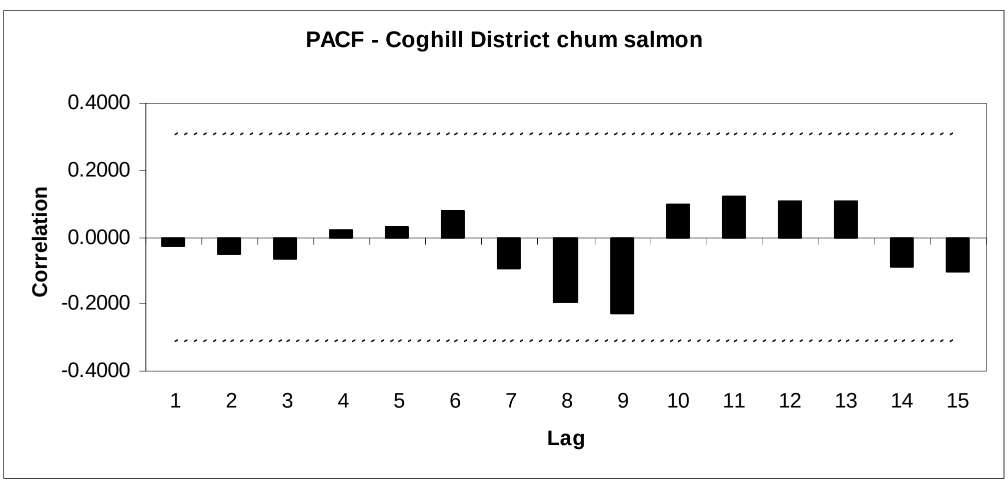
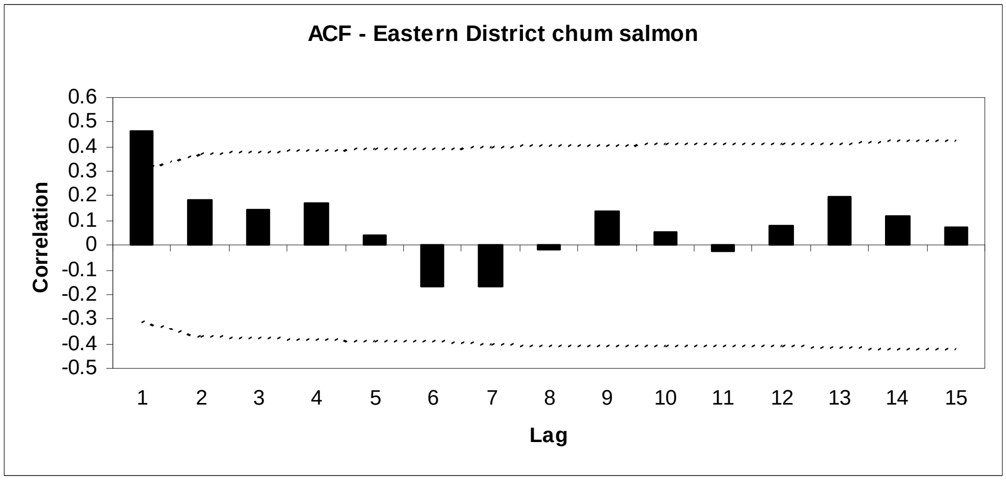


Figure 1.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Coghill District of Prince William Sound (1965 – 2004).



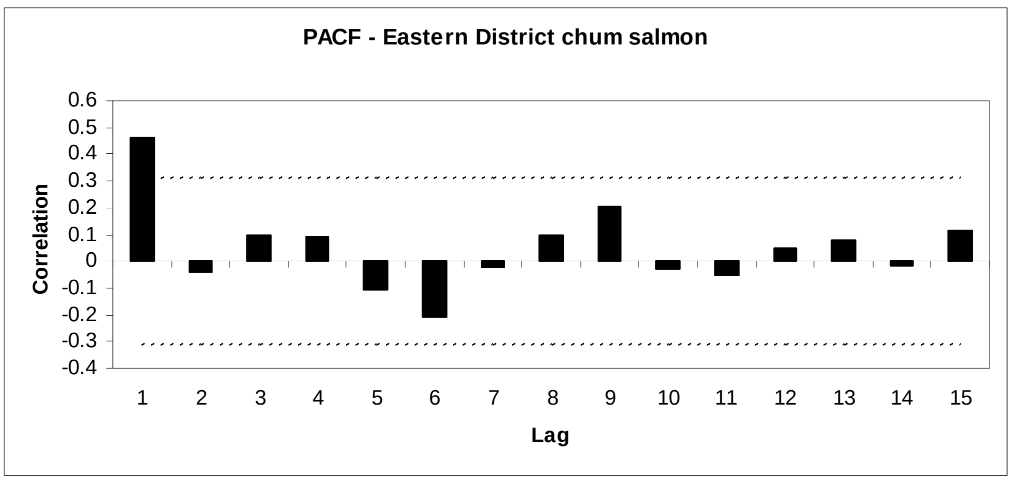


Figure 2.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Eastern District of Prince William Sound (1965 – 2004).

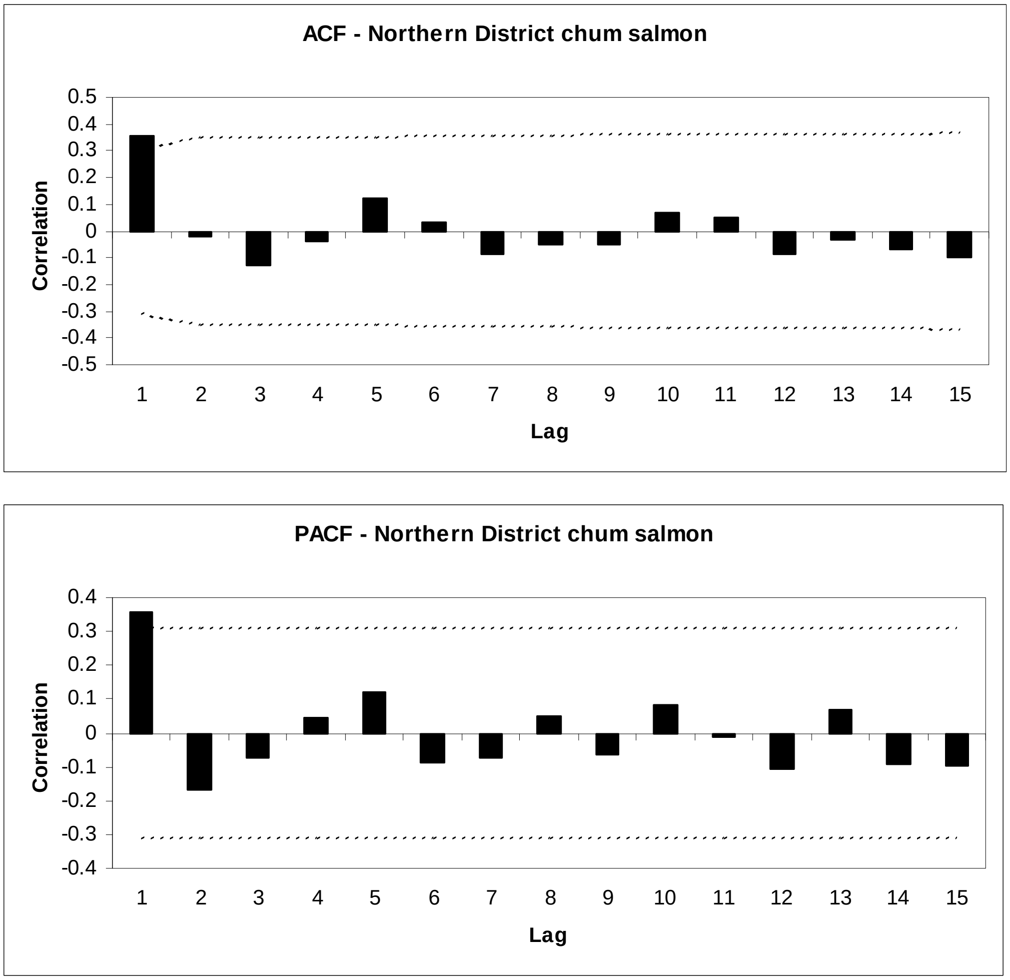
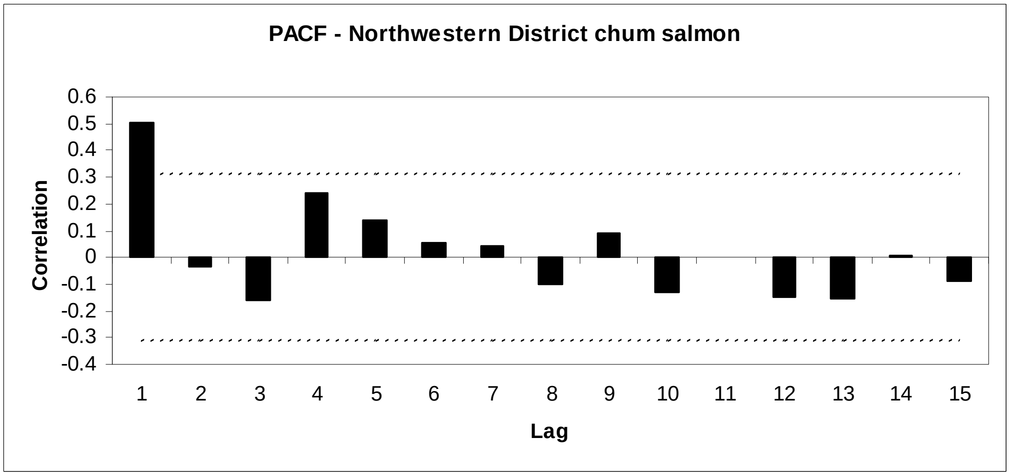


Figure 3.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Northern District of Prince William Sound (1965 – 2004).



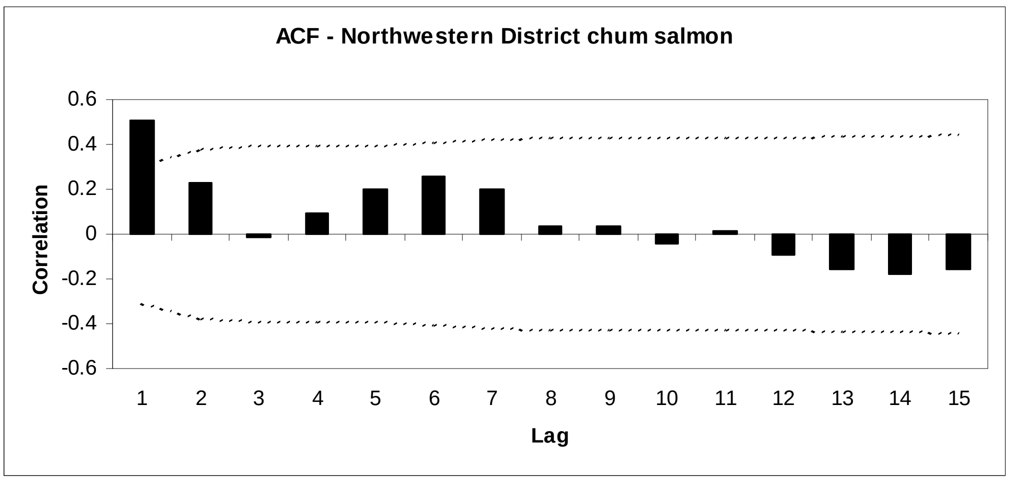


Figure 4.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Northwestern District of Prince William Sound (1965 – 2004).

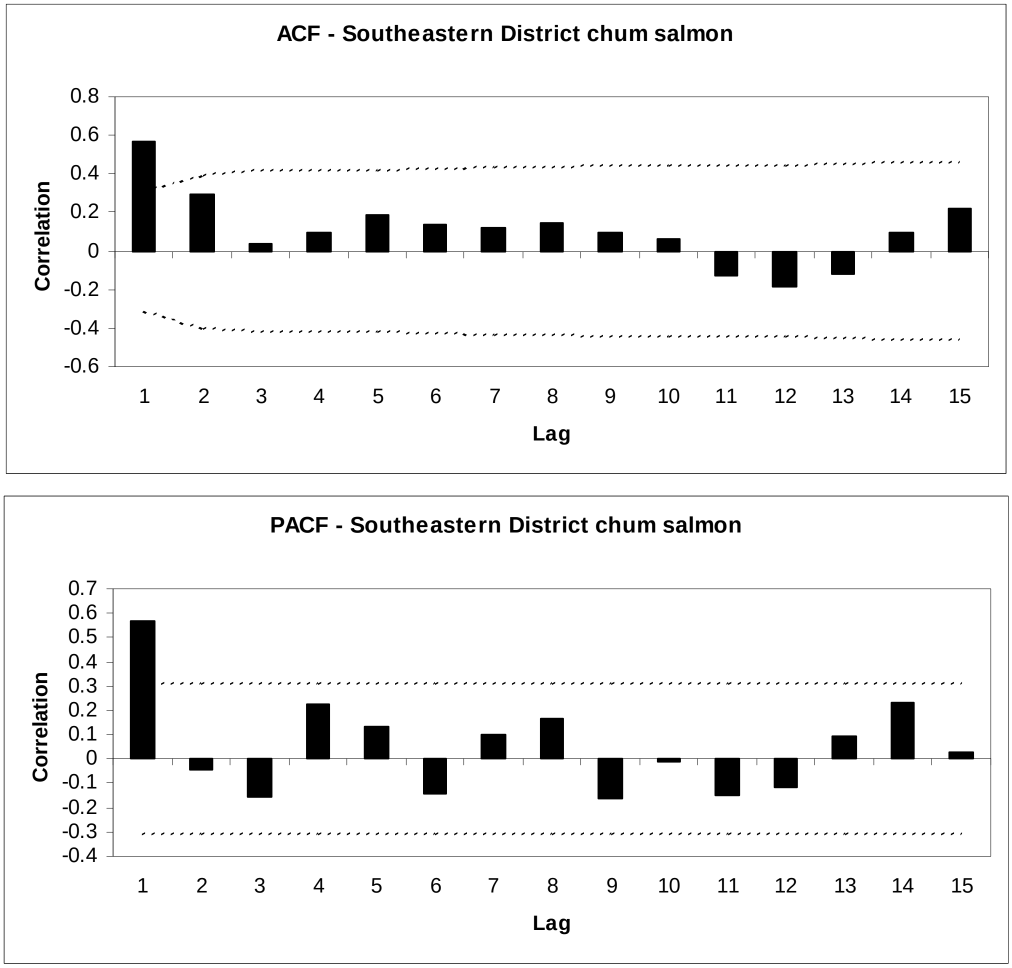


Figure 5.–Autocorrelations (ACF) and partial autocorrelations (PACF) for log annual observations of spawning abundance for chum salmon in the Southeastern District of Prince William Sound (1965 – 2004).

Table 4.–Length of time series of escapements (t), estimated log-transformed mean escapement ($\hat{\mu}$), lag-1 autoregressive term for Eastern, Northern, Northwestern, and Southeastern District chum salmon ($\hat{\phi}_x$), standard deviation of log-transformed escapement ($\hat{\sigma}$), and number of consecutive years (k = 3) to warrant a concern of chum salmon stocks in five fishing districts of Prince William Sound, Alaska.

Stock	t	$\hat{\mu}$	$\hat{\phi}_x$	$\hat{\sigma}$	k
Coghill District	40	9.56	NA	0.78	3 years
Eastern District	40	11.36	0.46	0.64	3 years
Northern District	40	10.37	0.35	0.72	3 years
Northwestern District	40	9.10	0.50	1.04	3 years
Southeastern District	40	9.58	0.57	1.13	3 years

Results and Discussion

Coghill District Chum Salmon

Using the time series of escapements since 1965, an escapement threshold of 9,000 resulted in a 2% estimated risk (once in 50 years) of concern, with a 3% estimated risk that a drop in mean escapement of 90% (from a mean of approximately 18,750 to the minimum observed escapement of approximately 2,050) would not be detected (Figure 6). Three consecutive escapements of less than 9,000 have occurred once (1967-1969) in the 40 years of chum salmon escapement since 1965 for an observed risk of 3%. This threshold value is very near the lower range value (8,000) of the current escapement goal. Hence, we recommend a SEG threshold of 8,000 chum salmon with a desire to maintain the average at 18,750 fish. Using available data since 1965, an escapement threshold of 12,500 resulted in an estimated risk of not detecting a drop in mean escapement of 80% that was approximately equal to the estimated risk of an unwarranted management concern (Figure 6).

Eastern District Chum Salmon

An escapement threshold of 50,000 resulted in a 5% estimated risk (once in 20 years) of a concern, with a 6% estimated risk that a drop in mean escapement of 85% (from a mean of approximately 103,100 to the minimum observed escapement of approximately 16,300) would not be detected (Figure 7). Three consecutive escapements of less than 50,000 have occurred once (1975-1977) in the 40 years of chum salmon escapements since 1965 for an observed risk of 3%.

This threshold value is the same as the lower range value of the current escapement goal. We recommend a SEG threshold of 50,000 chum salmon with a desire to maintain the average at 103,100 fish. An escapement threshold of 65,000 resulted in an estimated risk of not detecting a drop in mean escapement of 75% that was approximately equal to the estimated risk of an unwarranted management concern (Figure 7).

Northern District Chum Salmon

An escapement threshold of 20,000 resulted in a 2% estimated risk (once in 50 years) of a concern, with a 3% estimated risk that a drop in mean escapement of 90% (from a mean of approximately 40,100 to the minimum observed escapement of approximately 4,000) would not be detected (Figure 8). Three consecutive escapements of less than 20,000 has occurred twice (1968-1970 and 1969-1971) in the 40 years of chum salmon escapements since 1965 for an observed risk of 5%. This threshold value is the same as the lower range value of the current escapement goal. We recommend a SEG threshold of 20,000 chum salmon with a desire to maintain the average at 40,100 fish. An escapement threshold of slightly over 25,000 resulted in an estimated risk of not a detecting drop in mean escapement of 80% that was approximately equal to the estimated risk of an unwarranted management concern (Figure 8).

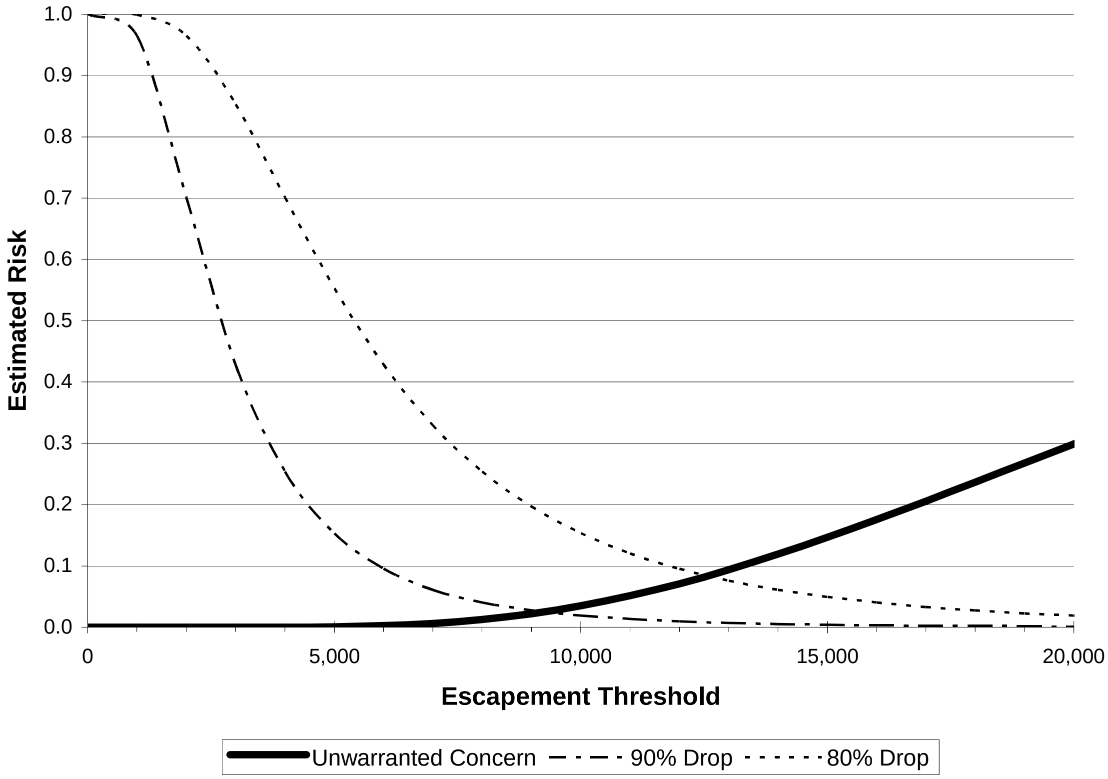


Figure 6.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Coghill District chum salmon.

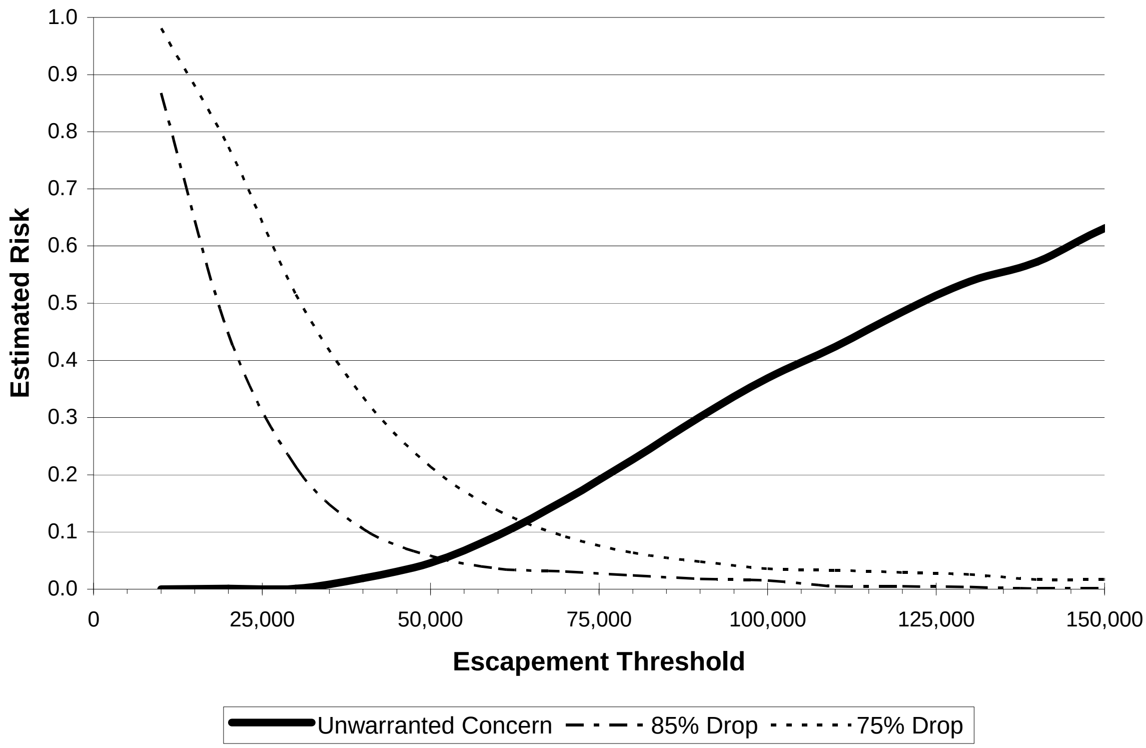


Figure 7.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Eastern District chum salmon.

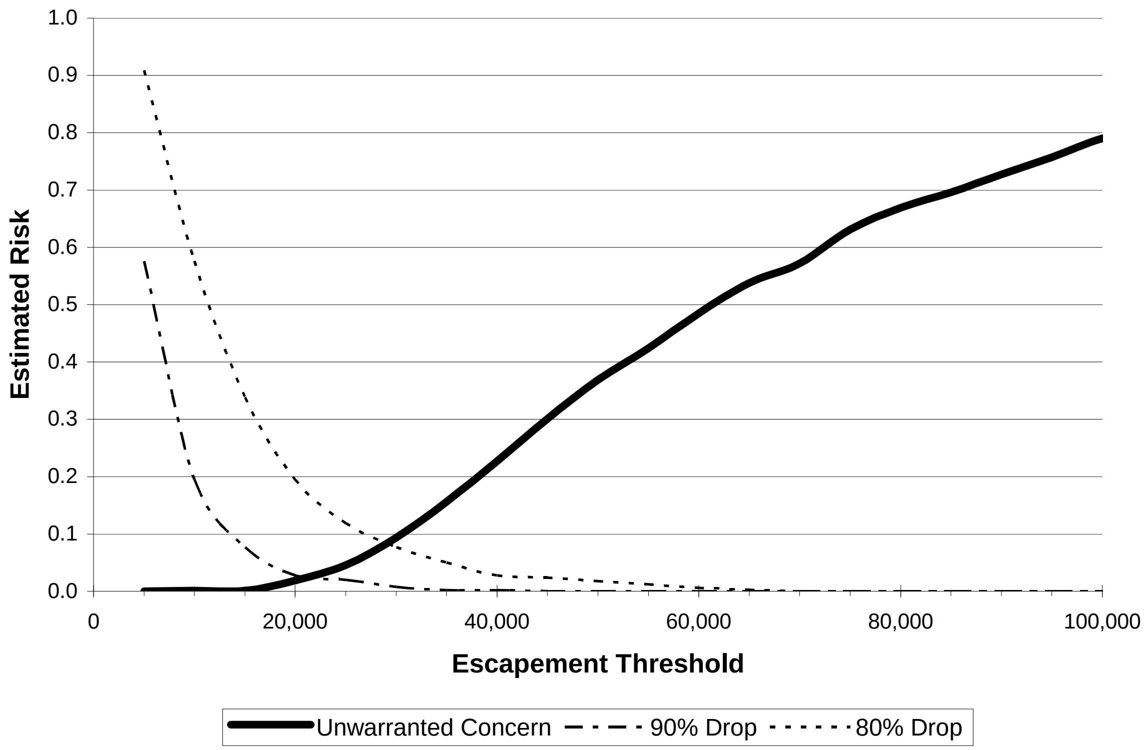


Figure 8.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Northern District chum salmon.

Northwestern District Chum Salmon

An escapement threshold of 4,000 resulted in a 4% estimated risk (once in 24 years) of a concern, with a 4% estimated risk that a drop in mean escapement of 95% (from a mean of approximately 13,000 to the minimum observed escapement of approximately 400) would not be detected (Figure 9). Three consecutive escapements of less than 4,000 has occurred twice (1967-1969 and 1968-1970) in the 40 years of chum salmon escapements since 1965 for an observed risk of 5%. This threshold value is near the lower range value (5,000) of the current escapement goal. We recommend a SEG threshold of 5,000 chum salmon with a desire to maintain the average at 13,000 fish. An escapement threshold of approximately 7,000 resulted in an estimated risk of not detecting a drop in mean escapement of 85% that was approximately equal to the estimated risk of an unwarranted management concern (Figure 9).

Southeastern District Chum Salmon

An escapement threshold of 6,000 resulted in a 8% estimated risk (once in 13 years) of a concern, with a 7% estimated risk that a drop in mean escapement of 95% (from a mean of approximately 25,000 to the minimum observed escapement of approximately 800) would not be detected (Figure 10). Three consecutive escapements of less than 6,000 have occurred once (1974-1976) in the 40 years of chum salmon escapements since 1965 for an observed risk of 3%. This threshold value is much lower than the lower range value (15,000) of the current escapement goal. The current SEG is based on a Ricker-type spawner-recruit analysis (Bue et al. 2002). Although a significant stock-recruit relationship was detected in this analysis, the resulting goal was called a SEG because of uncertainty in estimated escapements. Given the uncertainty in the escapement data and the lack of a directed fishery for this stock, we recommend a SEG threshold of 6,000 chum salmon with a desire to maintain the average at 25,000 fish. An escapement threshold of 10,000 resulted in an estimated risk of not detecting a drop in mean escapement of 85% that was approximately equal to the estimated risk of an unwarranted management concern (Figure 10).

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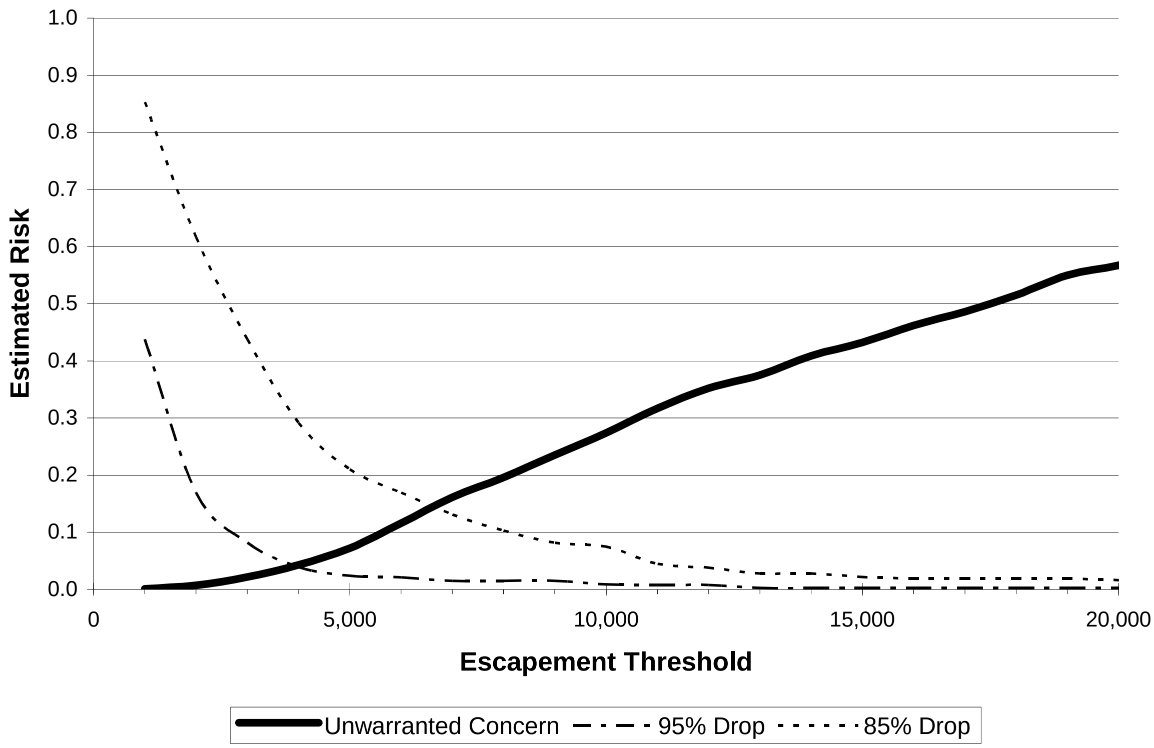

Figure 9.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Northwestern District chum salmon.

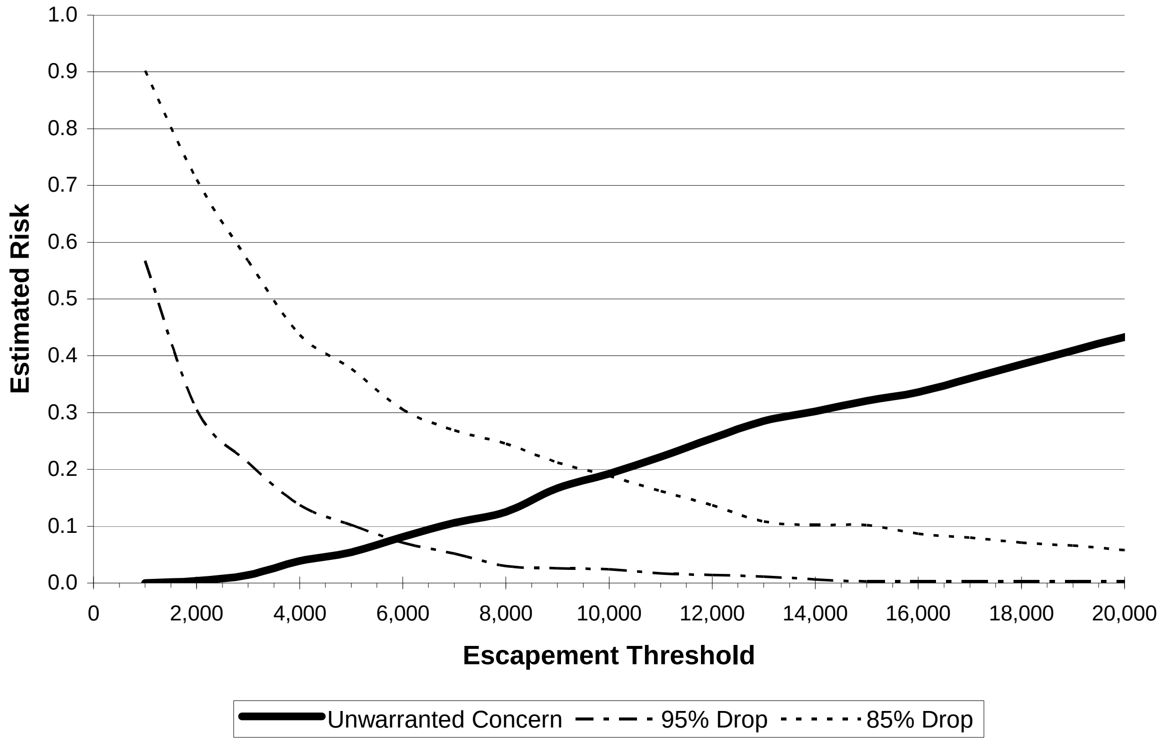

Figure 10.–Estimated risk of an unwarranted management concern and risk of not detecting various percentage drops in mean log-transformed escapement for a range of possible escapement thresholds for Southeastern District chum salmon.

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APPENDIX A
SUPPORTING INFORMATION FOR ESCAPEMENT GOALS FOR SALMON STOCKS IN THE COPPER RIVER, BERING RIVER, AND PRINCE WILLIAM SOUND AREA

Appendix A1.–Supporting information for analysis of escapement goal for Copper River Chinook salmon.

System: Copper River
Species: Chinook salmon

Data available for analysis of escapement goals.

Brood Year	Measured Escapement [a]	Modeled Escapement [b]	Total Return [c]
1980	ND	22,951	76,502
1981	ND	17,895	116,841
1982	ND	20,280	85,217
1983	ND	22,066	97,368
1984	ND	31,667	87,243
1985	ND	8,481	60,151
1986	ND	36,396	130,466
1987	ND	28,054	60,053
1988	ND	22,310	103,666
1989	ND	45,747	119,868
1990	ND	28,753	126,832
1991	ND	28,346	126,235
1992	ND	14,509	125,937
1993	ND	17,517	138,231
1994	ND	20,002	97,249
1995	ND	14,115	88,309
1996	ND	32,461	109,209
1997	ND	49,761	135,521
1998	ND	33,938	132,216
1999	16,157	17,125	95,542
2000	24,492	27,262	70,046
2001	28,208	28,202	80,237
2002	21,574	27,936	72,380
2003	34,078	36,480	93,553
2004	30,682	32,424	76,565

[a] Estimated by ADF&G mark-recapture experiment from 1999-2002 and from Native Village of Eyak experiments from 2003-2004.

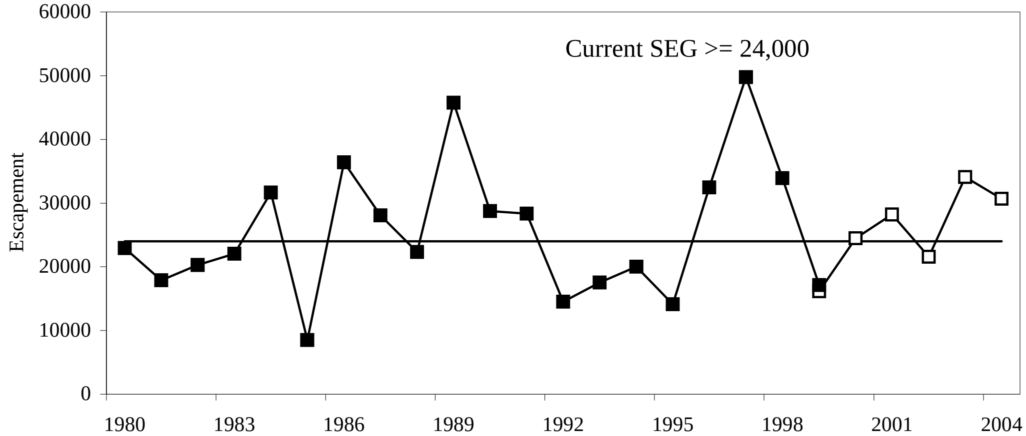
[b] From age-structured model (Savereide *In prep*).

[c] Total run estimated as sum of escapement estimates and subsistence, sport, and commercial harvests. For 1999-2004, measured escapements were used. For 1980-1998, modeled escapement estimates were used.

-continued-

System: Copper River
Species: Chinook salmon

Estimated escapement by year, estimated with an age-structured model (closed boxes) and ADF&G mark-recapture experiments (open boxes), and current SEG (solid line).



Appendix A2.–Supporting information for analysis of escapement goal for Bering River delta coho salmon.

System: Bering River Delta
Species: coho salmon

Data available for analysis of escapement goals.

Return	Wild	Harvest		Total
Year	Escapement [a]	Commercial	Sport [b]	Run [c]
1981	3,600	82,626	ND	86,226
1982	30,000	144,752	ND	174,752
1983	16,700	117,669	ND	134,369
1984	20,000	214,632	ND	234,632
1985	80,500	419,276	ND	499,776
1986	9,420	115,809	ND	125,229
1987	5,585	15,864	ND	21,449
1988	11,415	86,539	ND	97,954
1989	15,535	26,952	ND	42,487
1990	24,800	42,952	ND	67,752
1991	31,300	110,951	ND	142,251
1992	16,300	125,616	ND	141,916
1993	30,050	115,833	ND	145,883
1994	28,550	259,003	ND	287,553
1995	27,450	282,045	ND	309,495
1996	26,800	93,763	ND	120,563
1997	42,400	97	ND	42,497
1998	29,750	12,284	ND	42,034
1999	31,290	9,852	ND	41,142
2000	26,380	56,329	ND	82,709
2001	30,007	2,715	ND	32,722
2002	34,200	108,522	ND	142,722
2003	32,475	59,481	ND	91,956
2004	30,185	95,595	ND	125,780

[a] Calculated as peak aerial survey from the 7 primary index systems.
[b] There are no sport fish harvest estimates for the Bering River drainage.
[c] Escapement plus total harvest.

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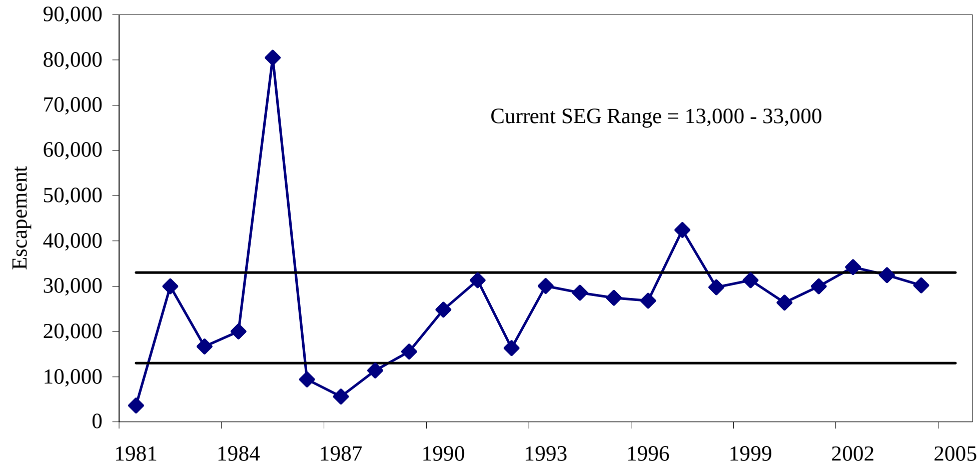
System: Bering River Delta
Species: coho salmon

Observed escapement by year (blocked line) and current SEG range (solid lines).



Appendix A3.–Supporting information for analysis of escapement goal for Copper River delta coho salmon.

System: Copper River Delta
Species: coho salmon

Data available for analysis of escapement goals.

Return Year	Wild Escapement [a]	Harvest Commercial	Harvest Sport [b]	Total Run [c]
1981	79,265	225,299	–	268,599
1982	43,300	310,154	–	350,479
1983	40,325	454,763	–	514,897
1984	60,050	234,243	84	300,548
1985	64,525	382,432	1,780	489,491
1986	25,790	295,980	649	324,739
1987	26,465	111,599	2,969	139,074
1988	27,620	315,568	1,010	342,280
1989	41,366	194,454	1,492	233,608
1990	42,386	246,797	2,118	287,011
1991	64,356	385,086	1,778	450,683
1992	44,563	291,627	1,941	339,494
1993	33,450	281,469	3,854	317,478
1994	45,555	677,633	4,139	725,881
1995	35,020	542,658	4,293	579,681
1996	47,110	193,042	2,543	244,902
1997	57,560	18,656	5,750	76,841
1998	30,750	108,232	2,825	142,462
1999	46,225	153,061	4,230	203,764
2000	43,130	304,944	6,978	352,253
2001	41,096	251,473	4,479	303,948
2002	89,815	504,223	12,144	598,547
2003	72,180	363,489	6,909	449,987
2004	99,980	467,859	14,443	582,007

[a] Calculated as peak aerial survey from the 18 primary index systems.

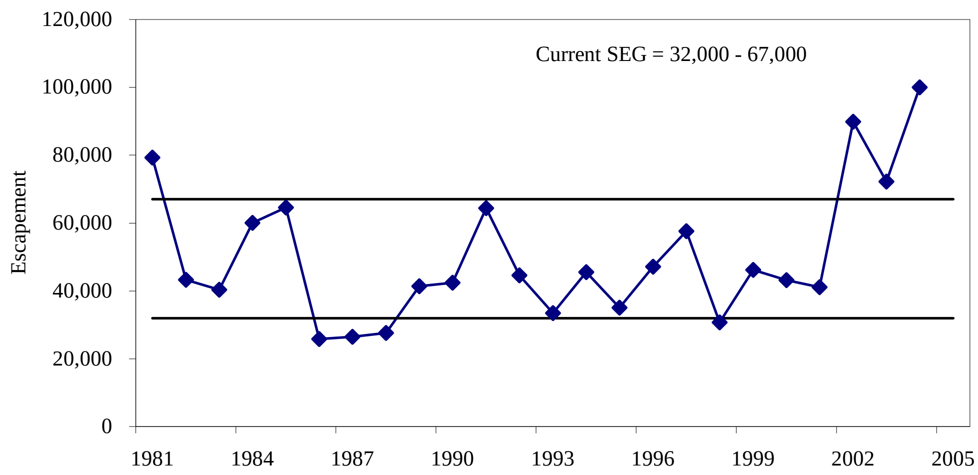
[b] From state-wide harvest survey.

[c] Escapement plus total harvest.

-continued-

System: Copper River Delta
Species: coho salmon

Observed escapement by year (blocked line) and current SEG range (solid lines).



Appendix A4.–Supporting information for analysis of escapement goal for Eshamy Lake sockeye salmon.

System: **Eshamy Lake**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

Brood Year (BY)	Wild Escapement	BY Total Return [b]	Recruits/ Spawner	Yield [c]
1970	11,460	11,690	1.02	230
1971	954	6,667	6.99	5,713
1972	28,683	59,976	2.09	31,293
1973	10,202	34,411	3.37	24,209
1974	633	15,946	25.19	15,313
1975	1,724	31,355	18.19	29,631
1976	19,367	178,061	9.19	158,694
1977	11,746	38,453	3.27	26,707
1978	12,580	36,904	2.93	24,324
1979	12,169	39,724	3.26	27,555
1980	44,263	270,623	6.11	226,360
1981	23,048	30,841	1.34	7,793
1982	6,782	51,290	7.56	44,508
1983	10,348	51,162	4.94	40,814
1984	36,121	117,761	3.26	81,640
1985	26,178	58,163	2.22	31,985
1986	6,949	39,946	5.75	32,997
1987 [a]	ND	ND	ND	ND
1988	31,747	93,876	2.96	62,129
1989	57,106	70,390	1.23	13,284
1990	14,191	58,447	4.12	44,256
1991	45,814	23,930	0.52	-21,884
1992	30,627	24,468	0.80	-6,159
1993	34,657	61,820	1.78	27,163
1994	23,910	54,750	2.29	30,840
1995	15,292	27,986	1.83	12,694
1996	5,271	65,804	12.48	60,533
1997	41,299	64,513	1.56	23,214
1998 [a]	ND	91,903	ND	ND

[a] Eshamy Lake weir was not in place in 1987 and 1998.

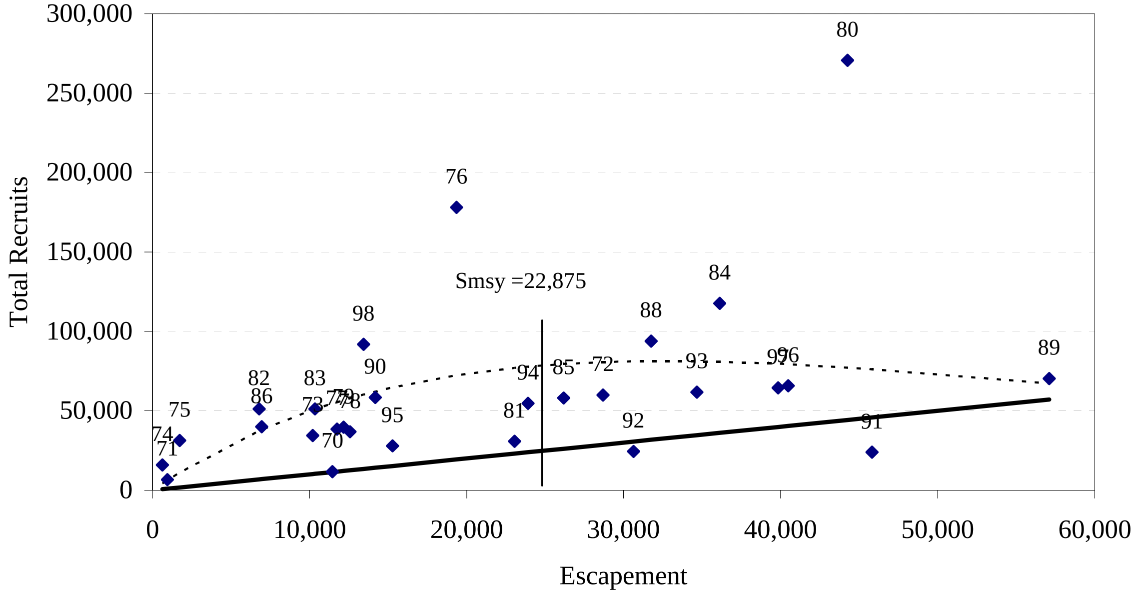
[b] Total run was calculated as Eshamy Lake weir escapement plus total Eshamy and Southwestern districts commercial harvests minus hatchery contribution estimates from sockeye salmon returning to Main Bay Hatchery. The Eshamy Lake wild contribution was then apportioned using run timing. The brood year return was calculated as the sum of returning adult offspring from a single brood year over multiple return years.

[c] Calculated as total brood year return minus brood year escapement.

-continued-

System: **Eshamy Lake**
Species: **sockeye salmon**

Fitted Ricker curve, line of replacement, and escapement-recruit data points labeled by brood year for Eshamy Lake sockeye salmon. Solid line is replacement; dotted line is estimated stock-recruit relationship (Ricker curve). S_{msy} is the escapement which will result in maximum sustained yield (maximum distance between Ricker curve and replacement line).



System: **Eshamy Lake**
Species: **Sockeye Salmon**

Yield Analysis

Escapement Bins (Thou.)	n	Average Escapement	Average Return	Average R/S	Average Yield	SD Yield
0-10	5	3,408	29,041	8.5	25,632	15,246
5-15	8	10,833	50,473	4.7	39,640	19,113
10-20	8	13,449	64,825	4.8	51,376	21,541
15-25	4	20,404	72,909	3.6	52,505	70,435
20-30	4	25,455	50,932	2.0	25,478	68,490
25-35	5	30,378	59,661	2.0	29,282	24,218
30-40	5	34,599	72,488	2.1	37,888	27,939
35-45	4	40,177	129,675	3.2	89,499	38,521
40-50	3	43,518	120,119	2.8	76,601	40,285
45-55	1	45,814	23,930	0.5	-21,884	–
50-60	1	57,106	70,390	1.2	13,284	–

Appendix A5.–Supporting information for analysis of escapement goal for Coghill Lake sockeye salmon.

System: **Coghill Lake**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

Brood Year (BY)	Wild Escapement	BY Total Smolt Production [b] Age-1	Age-2	Total	BY Total Return [c]	Recruits/ Spawner	Yield [d]
1962[a]	26,866	ND	ND	ND	54,520	2.0	27,654
1963[a]	63,984	ND	ND	ND	63,949	1.0	(35)
1964[a]	22,200	ND	ND	ND	163,130	7.3	140,930
1965[a]	62,500	ND	ND	ND	77,666	1.2	15,166
1966[a]	82,500	ND	ND	ND	86,158	1.0	3,658
1967[a]	33,000	ND	ND	ND	153,332	4.6	120,332
1968[a]	11,800	ND	ND	ND	137,508	11.7	125,708
1969[a]	81,000	ND	ND	ND	91,748	1.1	10,748
1970[a]	35,200	ND	ND	ND	220,866	6.3	185,666
1971[a]	15,000	ND	ND	ND	46,728	3.1	31,728
1972[a]	51,000	ND	ND	ND	218,568	4.3	167,568
1973[a]	55,000	ND	ND	ND	233,688	4.2	178,688
1974	22,334	ND	ND	ND	110,825	5.0	88,491
1975	34,855	ND	ND	ND	191,528	5.5	156,673
1976	9,056	ND	ND	ND	173,531	19.2	164,475
1977	31,562	ND	ND	ND	1,251,048	39.6	1,219,486
1978	42,284	ND	ND	ND	70,303	1.7	28,019
1979	48,281	ND	ND	ND	150,407	3.1	102,126
1980	142,253	ND	ND	ND	473,656	3.3	331,403
1981	156,112	ND	ND	ND	496,238	3.2	340,126
1982	180,314	ND	ND	ND	612,159	3.4	431,845
1983	38,783	ND	ND	ND	106,297	2.7	67,514
1984	63,622	ND	ND	ND	203,086	3.2	139,464
1985	163,342	ND	ND	ND	16,598	0.1	(146,744)
1986	74,135	ND	ND	ND	26,918	0.4	(47,217)
1987	187,263	369,822	6,779	376,601	60,053	0.3	(127,210)
1988	72,023	11,853	39,684	51,537	50,495	0.7	(21,528)
1989	36,881	124,024	ND	124,024	9,410	0.3	(27,471)
1990	8,250	ND	14,634	14,634	26,127	3.2	17,877
1991	9,701	274,977	33,100	308,077	153,809	15.9	144,108
1992	29,642	1,239,400	65,599	1,304,999	114,127	3.9	84,485
1993	9,232	1,534,392	42,660	1,577,052	67,466	7.3	58,234
1994	7,264	446,358	596,235	1,042,593	27,939	3.8	20,675
1995	30,382	596,235	ND	596,235	317,508	10.5	287,126

-continued-

System: **Coghill Lake**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

Brood Year (BY)	Wild Escapement	BY Total Smolt production [b] Age-1	Age-2	Total	BY Total Return [c]	Recruits/ Spawner	Yield [d]
1996	38,693	ND	ND	ND	133,471	3.5	94,778
1997	35,010	ND	ND	ND	44,736	3.3	62,440
1998	27,050	ND	ND	ND	89,490	1.3	9,726

[a] A partial weir and tower were used to enumerate sockeye salmon escapement into Coghill Lake.

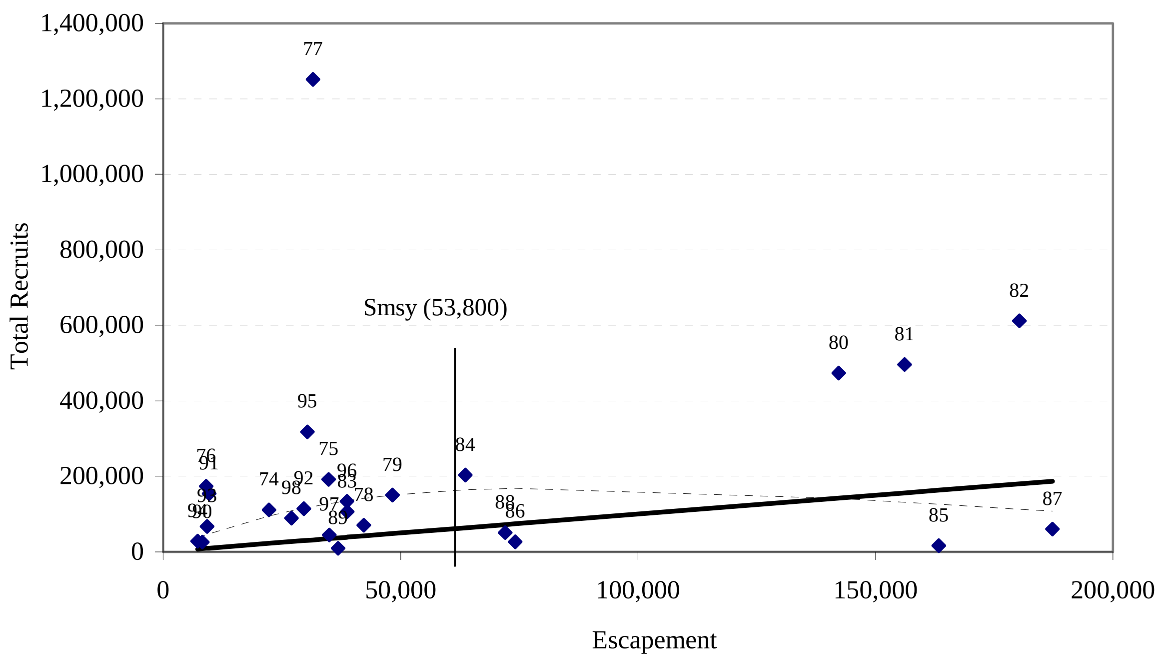
[b] The sockeye salmon smolt outmigration from Coghill Lake was estimated using incline plane traps and mark-recapture techniques, 1989-1991 and 1993-1997.

[c] Total run was calculated as Coghill Lake weir escapement plus total Coghill District commercial harvest minus hatchery contribution estimates from sockeye salmon returning to Main Bay Hatchery. The brood year return was calculated as the sum of returning adult offspring from a single brood year over multiple return years.

[d] Calculated as total brood year return minus brood year escapement.

System: **Coghill Lake**
Species: **sockeye salmon**

Fitted Ricker curve, line of replacement, and escapement-recruit data points labeled by brood year for Coghill Lake sockeye salmon. Solid line is replacement; dotted line is estimated stock-recruit relationship (Ricker curve). S_{msy} is the escapement which will result in maximum sustained yield (maximum distance between Ricker curve and replacement line).



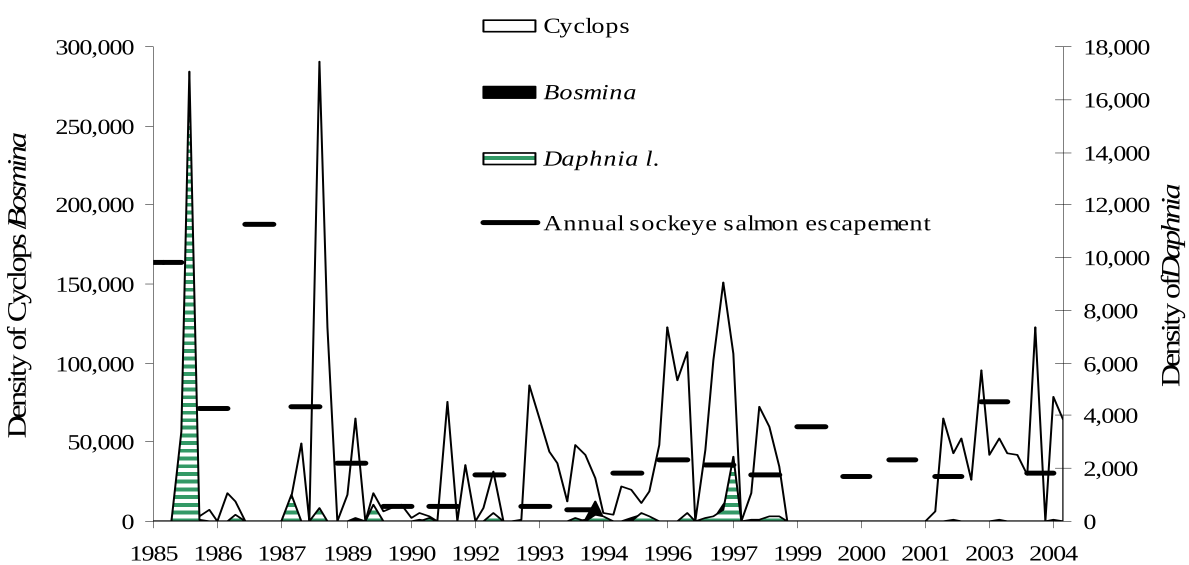
System: **Coghill Lake**
Species: **sockeye salmon**

Yield Analysis

Escapement Bins (Thou.)	n	Average Escapement	Average Return	Average R/S	Average Yield	SD Yield
0 - 20	5	8,701	89,774	10.3	81,074	69,088
10 - 30	3	26,342	104,814	4.0	66,007	35,530
20 - 40	9	32,035	262,115	8.2	193,308	387,101
30 - 50	8	37,481	283,162	7.6	208,987	473,989
40 - 60	2	45,283	110,355	2.4	65,073	52,401
50 - 70	1	63,622	203,086	3.2	139,464	
60-80	3	69,927	93,500	1.3	23,573	101,183
70-90	2	73,079	38,706	0.5	-34,373	18,165
80-100	0	–	–	–	–	–
90-110	0	–	–	–	–	–
100-120	0	–	–	–	–	–
110-130	0	–	–	–	–	–
120-140	0	–	–	–	–	–
130-150	1	142,253	473,656	3.3	331,403	
140-160	2	149,183	484,947	3.3	335,765	6,168
150-170	2	159,727	256,418	1.6	96,691	344,269
160-180	1	163,342	16,598	0.1	-146,744	
170-190	2	183,789	336,106	1.8	152,318	395,311

System: **Coghill Lake**
Species: **sockeye salmon**

Average monthly (June through October) density (no/m3) of the three primary zooplankters in Coghill Lake, 1985 - 1986, 1988 - 1998, 2002 - 2004. No zooplankton data are available from 1987, 1999 - 2001.



Appendix A6.–Supporting information for analysis of escapement goal for Bering River sockeye salmon.

System: **Bering River**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

Return Year	Wild Escapement [b]	Commercial Harvest	Total Run [c]
1983 [a]	41,200	179,273	–
1984 [a]	48,500	91,784	–
1985 [a]	24,300	26,561	–
1986	18,975	19,038	38,013
1987	26,525	16,926	43,451
1988	13,330	7,152	20,482
1989	23,300	9,225	32,525
1990	19,741	8,332	28,073
1991	32,220	19,181	51,401
1992	55,895	19,721	75,616
1993	27,725	33,951	61,676
1994	26,550	27,926	54,476
1995	33,450	21,585	55,035
1996	27,310	37,712	65,022
1997	13,065	9,651	22,716
1998	23,400	8,439	31,839
1999	46,195	13,697	59,892
2000	24,220	1,279	25,499
2001	8,423	5,450	13,873
2002	24,715	235	24,950
2003	32,840	18,266	51,106
2004	23,260	13,165	36,425

[a] Before 1986, Kayak Island subdistrict was included in the total harvest inflating the total run estimates. Therefore, the total run data are only shown for 1986 through 1995.

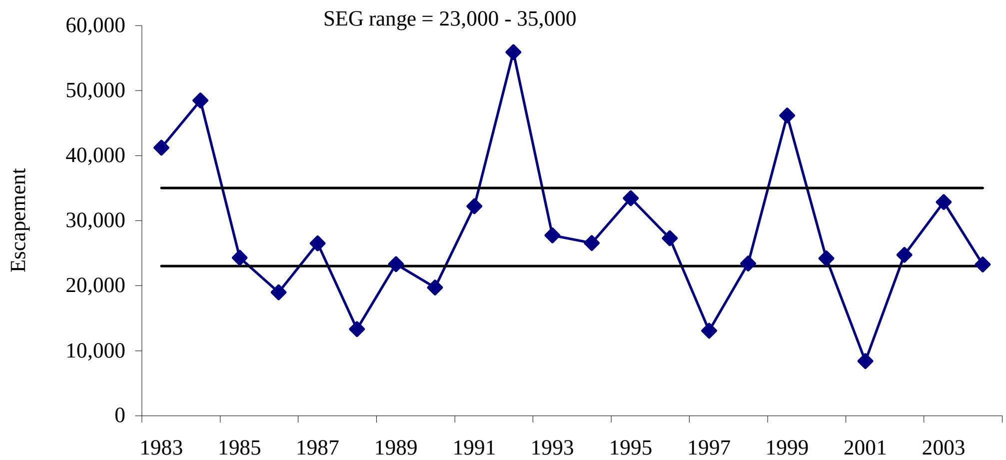
[b] Calculated as peak aerial survey from the 7 primary index systems.

[c] Wild escapement plus commercial harvest.

-continued-

System: **Bering River**
Species: **sockeye salmon**

Observed escapement by year (blocked line) and current SEG range (solid lines).



Appendix A7.–Supporting information for analysis of escapement goal for Copper River delta sockeye salmon.

System: **Copper River Delta**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

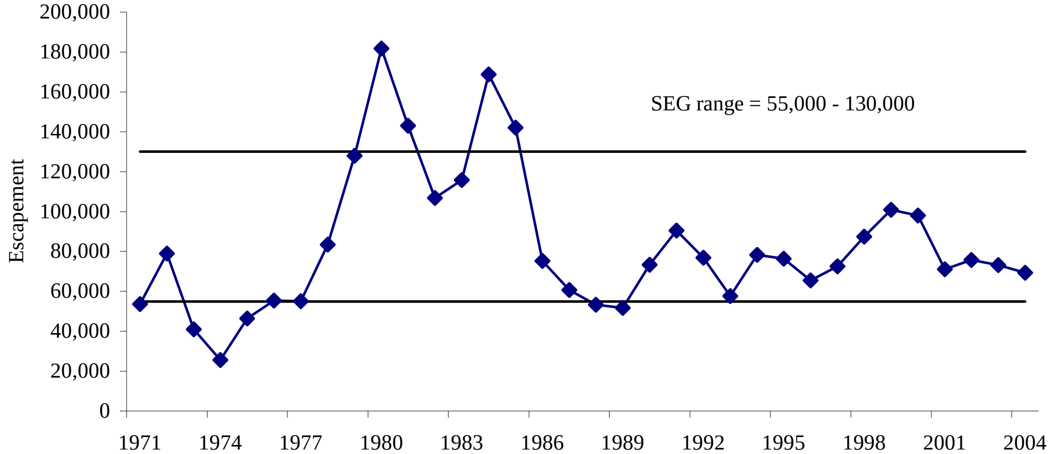
Brood Year	Escapement [a]
1971	53,647
1972	78,942
1973	40,970
1974	25,651
1975	46,475
1976	55,450
1977	55,144
1978	83,469
1979	127,900
1980	181,750
1981	143,050
1982	106,770
1983	115,750
1984	168,840
1985	142,050
1986	75,295
1987	60,698
1988	53,315
1989	51,700
1990	73,345
1991	90,500
1992	76,827
1993	57,720
1994	78,370
1995	76,370
1996	65,470
1997	72,563
1998	87,500
1999	100,925
2000	98,045
2001	71,065
2002	75,735
2003	73,150
2004	69,385

[a] Escapement calculated as the peak aerial counts from 21 survey sites.

-continued-

System: **Copper River Delta**
Species: **sockeye salmon**

Observed escapement by year (blocked line) and current SEG range (solid lines)



Appendix A8.–Supporting information for analysis of escapement goal for Upper Copper River sockeye salmon.

System: **Upper Copper River**
Species: **sockeye salmon**

Data available for analysis of escapement goals.

Brood Year	Wild Escapement [a]	Harvest [b] Sport	Harvest [b] Subsistence/ Personal Use	Yield [c]
1978	67,861	1,606	25,783	1,179,327
1979	168,733	1,599	33,096	1,580,459
1980	199,730	2,109	31,041	912,140
1981	434,954	1,523	65,168	439,615
1982	338,182	3,343	105,432	1,423,953
1983	387,884	2,619	110,794	383,640
1984	431,026	3,267	76,177	835,653
1985	327,719	4,752	61,551	711,235
1986	383,377	4,129	68,495	1,226,741
1987	350,372	4,876	76,598	1,364,089
1988	291,856	3,038	71,525	1,364,013
1989	373,169	4,509	84,138	1,710,880
1990	397,085	3,569	98,197	1,385,160
1991	353,718	5,511	117,188	2,521,865
1992	371,149	4,560	131,956	2,567,484
1993	551,926	5,288	146,724	1,863,980
1994	441,745	6,533	162,301	1,210,765
1995	344,289	6,068	131,522	921,193
1996	572,797	11,851	147,059	923,621
1997	734,436	12,293	231,534	849,202
1998	488,616	11,184	201,624	1,193,674
1999	424,777	11,101	219,027	944,480
2000	294,932	12,361	167,353	–
2001	492,400	8,169	214,966	–
2002	556,119	7,761	145,417	–
2003	466,230	7,108	134,018	–
2004	431,959	6,446	182,703	–

[a] Wild spawning escapements estimated as the adjusted Miles Lake sonar index minus subsistence, personal use, and sport harvests and minus the Gulkana Hatchery broodstock and excess brood escapements.

[b] The sport and subsistence/personal use harvests include both wild and hatchery stocks. Prior to 1995, scanning for coded-wire tags or otolith marks was not implemented in the Upper Copper River subsistence or personal use fisheries.

[c] Yield is total brood year total return minus brood year escapement. Shown is the total yield for both Upper Copper River and the Copper River delta because the stock groups in the commercial harvest cannot be separated.

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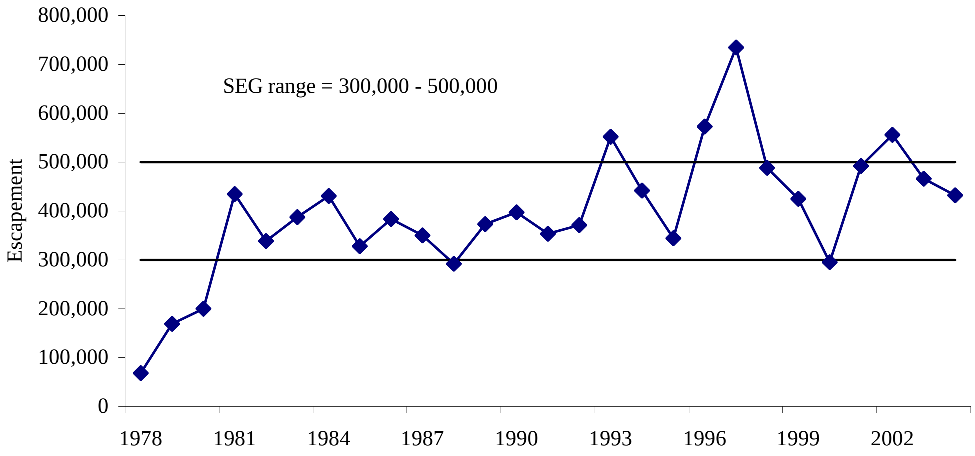
System: **Upper Copper River**
Species: **sockeye salmon**

Observed escapement by year (blocked line) and current SEG range (solid lines)



Appendix A9.–Supporting information for analysis of escapement goal for Prince William Sound pink salmon even-year broodline (all districts combined).

System: **Prince William Sound**
Species: **pink salmon**
Stock Unit: **even year**

Data available for analysis of escapement goals.

Brood Year	Wild Escapement [a]	Intertidal Fry Density [b]	Yield [c]
1960	1,350,722		7,409,604
1962	2,018,010	146.74	4,030,566
1964	1,841,680	116.71	2,280,908
1966	1,423,170	80.98	2,185,508
1968	1,156,510	187.38	2,632,706
1970	979,220	123.10	(283,257)
1972	641,180	99.20	765,713
1974	958,120	157.30	2,987,135
1976	926,260	179.90	2,897,594
1978	1,145,010	237.23	13,067,293
1980	1,671,940	164.73	14,671,058
1982	2,274,570	327.37	19,571,165
1984	4,031,860	200.67	1,764,097
1986	960,220	221.61	906,716
1988	964,530	242.97	13,454,166
1990	1,325,852	176.72	862,358
1992	555,105	61.60	8,889,016
1994	1,413,184	221.24	6,240,973
1996	1,483,336	ND	4,257,643
1998	1,420,105	ND	6,086,528
2000	1,659,028	ND	(393,986)
2002	943,177	ND	3,957,586
2004	1,996,223	ND	

[a] The pink salmon escapement index is estimated from the area under the curve of weekly aerial survey counts adjusted for an average 17.5 days stream life factor.

[b] Intertidal fry density was measured as the average number of live eggs and fry per m^2 of intertidal stream bottom. Fry densities were last estimated in spring, 1995.

[c] Yield is total return minus brood year escapement. Total wild pink salmon harvest was estimated by subtracting hatchery reared fish marked with coded-wire tags (CWT) or with thermally marked otoliths from total commercial harvest.

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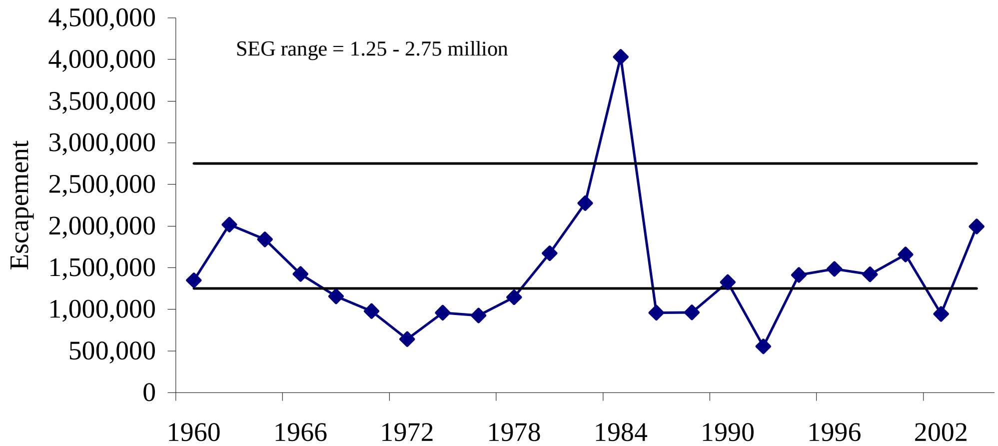
System: **Prince William Sound**
Species: **pink salmon**
Stock Unit: **even year**

Observed escapement by year (blocked line) and recommended SEG range (solid lines).



Appendix A10.–Supporting information for analysis of escapement goal for Prince William Sound pink salmon-odd year broodline (all districts combined).

District: **Prince William Sound**
Species: **pink salmon**
Stock Unit: **odd year**

Data available for analysis of escapement goals.

Brood Year	Wild Escapement [b]	Intertidal Fry Density [c]	Yield [d]
1961	2,198,980	285.09	4,452,138
1963	1,355,740	251.38	2,080,687
1965	975,956	197.98	2,492,644
1967	842,260	136.81	4,390,889
1969	404,570	254.65	8,018,944
1971	1,112,550	118.07	2,169,338
1973	1,225,010	162.85	4,493,355
1975	1,265,560	311.24	4,120,507
1977	1,298,170	305.21	15,977,422
1979	2,217,280	356.67	18,009,653
1981	1,713,080	537.15	9,148,037
1983	2,163,100	364.75	18,051,533
1985	2,621,330	372.96	10,860,291
1987	1,466,240	285.81	5,338,102
1989	1,272,770	270.56 [a]	8,022,686
		330.00 [a]	
1991	1,837,165	212.54	1,029,203
1993	1,066,469	220.30	2,325,832
1995	1,190,184	242.75	3,199,402
1997	1,422,688	ND	7,991,096
1999	2,462,871	ND	6,364,497
2001	2,000,386	ND	5,389,311
2003	2,857,289	ND	

[a] Two rounds of fry digs were completed in 1989.

[b] The pink salmon escapement index is the area under the curve of weekly aerial survey counts adjusted for an average 17.5 days stream life factor.

[c] Intertidal fry density was measured as the number of live eggs and fry per m^2 of intertidal stream bottom. Fry densities were last estimated in spring, 1995.

[d] Yield is total return minus brood year escapement. Total wild pink salmon harvest was estimated by subtracting hatchery reared fish marked with coded-wire tags (CWT) or with thermally marked otoliths from total commercial harvest.

-continued-

District: **Prince William Sound**
Species: **pink salmon**
Stock Unit: **odd year**

Observed escapement by year (blocked line) and recommended SEG range (solid lines).